

5           An analysis system for analysing the condition of a machine

### Technical Field of the Invention

The present invention relates to an apparatus for analysing the condition of a machine, and to a system for analysing the condition of a machine. The invention  
10   also relates to method of operating such a system.

### Description of Related Art

Machines with moving parts are subject to wear with the passage of time, which often causes the condition of the machine to deteriorate. Examples of such machines  
15   with movable parts are motors, pumps, generators, compressors, lathes and CNC-machines. The movable parts may comprise a shaft and bearings.

In order to prevent machine failure, such machines should be subject to maintenance, depending on the condition of the machine. Therefore the operating condition of  
20   such a machine is preferably evaluated from time to time. The operating condition can be determined by measuring vibrations emanating from a bearing or by measuring temperature on the casing of the machine, which temperatures are dependent on the operating condition of the bearing. Such condition checks of machines with rotating or other moving parts are of great significance for safety and  
25   also for the length of the life of such machines. It is known to manually perform such measurements on machines. This ordinarily is done by an operator with the help of a measuring instrument performing measurements at measuring points on one or several machines.

30   A number of commercial instruments are available, which rely on the fact that defects in rolling-element bearings generate short pulses, usually called shock pulses. State of the art shock pulse measuring apparatuses may include proprietary technology for generating a value indicative of the condition of a bearing or a machine.

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WO 98/01831 discloses a machine having a measuring point and a shaft with a certain shaft diameter, wherein the shaft can rotate when the machine is in use. WO 98/01831 also discloses an apparatus for analysing the condition of a machine having a rotating shaft. The disclosed apparatus has a sensor for producing a measured value indicating the vibration or temperature at the measuring point. The apparatus disclosed in WO 98/01831 has a microprocessor and an analysis routine stored in a memory. According to WO 98/01831 the following process can be performed by running the analysis routine on the microprocessor:

- producing the measured value;
- 15 - acquiring interpretation information from an information carrier which is mounted by the measuring point;
- producing an actual condition value, indicating the actual condition of the machine at the measuring point, dependent on the measured value and the interpretation information;
- 20 - acquiring a second condition value, indicating the condition of the machine at measuring point at an earlier point of time, from the information carrier;
- producing a relation value dependent on the actual condition value and the second condition value, which relation value indicates a change in the condition.

## 25 Summary

An aspect of the invention relates to the problem of providing a system achieving a cost-effective improvement of the length of life of machines having a rotating shaft while making it easy for a user to achieve cost-effective machine condition monitoring.

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This problem is addressed by a system for analysing the condition of a machine having a rotating shaft and a machine body with a measuring point ; the system

- 5 comprising a client part connectable to a communications network for communication with a supplier part computer; said client part comprising:
- a sensor attachable on or at said measuring point for generating measurement data dependent on rotation of said shaft;
  - an analysis apparatus for analysing the condition of the machine on the basis
  - 10 of said measurement data; said analysis apparatus having
    - at least one input for receiving said measurement data;
    - a data processing means for processing condition data dependent on said measurement data; said data processing means comprising means for performing a plurality of condition monitoring
    - 15 functions; and
    - a logger for registering use of at least one of said condition monitoring functions
    - a communication port coupled to said data processing means and connectable to said communications network for
    - 20 communication with said supplier part computer; wherein
    - said analysis apparatus is adapted to deliver information indicative of said registered use on said communication port for delivery to said supplier part computer.
- 25 This solution advantageously enables a user to use machine condition monitoring functions at a pay-per-use basis while saving the user from first having the hassle of obtaining a number of prepaid credits. Instead the user may use any function at his or her leisure, and the apparatus itself will deliver the registered amount of use to a supplier at regular intervals. The delivery of registered amount of use may be
- 30 achieved by docking the apparatus in a battery-charge-and-usage-report- docking station. This solution may be preferable for a battery operated embodiment of the apparatus. Alternatively the apparatus may be connected from time to time to a communications network capable of exchanging information between a supplier part

5 and the apparatus. Alternatively the apparatus may be connected to a user computer which in turn is connectable to such a communications network.

According to an embodiment said logger is adapted to register use of a first condition monitoring function a first rate; and

10 said logger is adapted to register use of a second condition monitoring function at a second rate.

According to an embodiment said second rate is such that use registered at said second rate causes a higher cost per unit of usage than use registered at said first  
15 rate.

According to an embodiment said second rate is such that use registered at said second rate causes a lower cost per unit of usage than use registered at said first rate.

20 According to an embodiment said registered use is a parameter indicative of a number of executions of at least one of said condition monitoring functions.

According to an embodiment said registered use is a parameter indicative of an extent of time.

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According to an embodiment there is provided an apparatus for analysing the condition of a machine having a rotating shaft and a machine body with a measuring point, comprising:

a sensor attachable on or at said measuring point for generating  
30 measurement data dependent on rotation of said shaft;  
data processing means for processing condition data dependent on said measurement data; said data processing means comprising means for performing a plurality of condition monitoring functions;

5 a logger for registering use of at least one of said condition monitoring functions

a communication port coupled to said data processing means; wherein said analysis apparatus is adapted to deliver information indicative of said registered use on said communication port;

10 This solution advantageously enables delivery of information indicative of an amount of use of condition monitoring functions to a supplier part computer.

An aspect of the invention relates to the problem of providing equipment for  
15 analysing the condition of a machine satisfying the conflicting requirements of reducing the price for a piece of condition monitoring equipment while maintaining profitability for the supplier of the analysis system.

This problem is addressed by an apparatus for analysing the condition of a machine,  
20 comprising an apparatus for analysing the condition of a machine, comprising:

at least one input for receiving measurement data from a sensor for surveying a measuring point of the machine;

data processing means for processing condition data dependent on said measurement data; said data processing means comprising means for performing a  
25 plurality of condition monitoring functions; and

a logger for registering use of at least one of said condition monitoring functions.

This advantageously enables charging a cost for use of the apparatus.

30 An embodiment of the apparatus comprising:

a communication port; wherein

said apparatus is adapted to be capable of delivering data indicative of said registered use on said communication port.

- 5 This advantageously enables delivery of use info to a supplier, for charging a cost.  
i.e. reporting the amount of use to the supplier.

An embodiment of the apparatus further comprises:

- means for comparing said registered use with a first reference value,  
10 means for disabling said data processing means or at least one of said  
condition monitoring functions in response to the outcome of said comparison.  
This solution encourages a user to buy additional usage so as to maintain operability  
of desired functions of the analysis apparatus. Such additional usage may be in the  
form of a number of measurements using a desired function, or a period of time the  
15 duration of which is defined by the registered use and the first reference value.

An embodiment of the apparatus further comprises: key reception means adapted to  
allow further use of said data processing means in response to reception of a first  
key.

- 20 This advantageously enables a supplier to amend the relation between a registered  
use value and the reference value. Thereby it is possible to increase "the stored  
amount of use" available before the data processing means is disabled.

An embodiment of the apparatus further comprises:

- 25 key reception means adapted to allow further use of a selected one of said condition  
monitoring functions in response to reception of a key associated with said selected  
function.

- This advantageously enables a supplier to amend the relation between the reference  
value and a registered use value for a selected function. Thereby it is possible to  
30 increase "the stored amount of use" available before the selected function is  
disabled.

An embodiment of the apparatus further comprises:

means for reading a current value of said registered use;

- 5 means for comparing said current value with a second reference value;  
means for registering use at a first rate when said current value is above  
the second reference value; and  
means for registering use at a second rate when said current value is  
below the second reference value.
- 10 This advantageously enables a supplier to sell usage at different costs. When,  
according to one embodiment, a user has paid for a certain amount  $A_p$  of usage, the  
second reference value is a level indicating that the whole amount  $A_p$  of usage has  
been spent. This means that any further use will be usage which has not yet been  
paid for. By the feature of registering such further use at a second rate it is possible  
15 to charge a higher cost per unit of usage for such further use.

An embodiment of the apparatus wherein:

at least some of said plurality of condition monitoring functions is at least  
partly embodied by computer program code.

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An aspect of the invention relates to the problem of achieving a cost-effective  
improvement of the length of life of machines with a moving part.

An aspect of the invention relates to the problem of achieving an analysis apparatus  
25 for evaluating the condition of a machine,

This problem is addressed by

An apparatus for monitoring the condition of a machine, comprising:

at least one input for receiving measurement data from a sensor for  
surveying a measuring point of the machine;

30 data processing means for processing condition data dependent on said  
measurement data; said data processing means comprising means for performing at  
least two condition monitoring functions;

5           at least one of said plurality of condition monitoring functions having a locked state and an unlocked state; said locked state prohibiting complete execution of said condition monitoring function; and said unlocked state allowing execution;

          means for changing the state of a selected condition monitoring function between the locked state and the unlocked state.

10           This advantageously provides the analysis apparatus with an improved versatility. A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in several versions. More precisely, an apparatus having two individually lockable/unlockable functions can be provided in the following

15   versions:

          with only the first function unlocked;

          with only the second function unlocked;

          with the first function and the second function unlocked.

20   Hence, a supplier can offer the apparatus in three versions, and this allows for selling it at different price levels dependent on the functionality included. Each client is therefore provided with a choice as to which functions to choose.

An embodiment of the apparatus further comprises:

25           key reception means adapted to allow use of a selected one of said condition monitoring functions in response to reception of a key associated with said selected function;

          a logger for registering use of at least one of said condition monitoring functions.

30           means for comparing said registered use with a first reference value,  
          means for disabling said data processing means or at least one of said condition monitoring functions in response to the outcome of said comparison.



- 5 Hence, A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in more than four versions:

with only the first function unlocked;  
with only the second function unlocked;  
with the first function and the second function unlocked.

- 10 with both functions locked but each function individually or collectively ununlockable for a limited amount of use.

### **Brief Description of the Drawings**

- 15 For simple understanding of the present invention, it will be described by means of examples and with reference to the accompanying drawings, of which:

Fig. 1 shows a schematic block diagram of an embodiment of a condition analyzing system according to an embodiment of the invention.

- 20 Fig. 2 is a schematic block diagram of an embodiment of a part of the condition analyzing system 2 shown in Fig 1.

Figure 3 is a simplified illustration of an embodiment of a memory and its contents.

Figure 4 is a simplified illustration of a second embodiment of the memory and its contents.

- 25 Figures 5A and 5B show a flow chart illustrating an embodiment of a procedure according to the invention.

Figure 5C is a simplified illustration of a principle of an embodiment of an account value or amount of usage parameter.

- Figure 5D is an illustration of a principle of an embodiment wherein the cost per use  
30 changes after a certain level of use has been attained.

Figure 6 is a flow chart illustrating an embodiment of a procedure according to the invention.

Figure 7 is a physical embodiment of an apparatus.

Figure 8 is a side view of the apparatus shown in Figure 7.

5 **Figure 9** illustrates the apparatus, shown in **Figure 7**, being gripped by a hand 140 of a user.

**Figure 10** is a top view of an embodiment of the apparatus, illustrating the physical dimensions thereof.

**Figure 11** is a side view of the apparatus shown in **Figure 10**.

10 **Figure 12** is a block diagram of an embodiment of the apparatus shown in **Figure 1** and/or **Figures 7** and **8**.

**Figure 13A** illustrates a part of memory 60 comprising a function  $F_k$  and an associated status field 142.

15 **Figure 13B** illustrates a part of memory 60 according to an embodiment, comprising a function  $F_k$  and an associated status field 142<sub>k</sub>.

**Figure 14** is a flow chart illustrating an embodiment of a procedure for delivering an apparatus, and for adding use or functionality to the apparatus by means of a key from the supplier.

20 **Figure 15** shows a schematic block diagram of another embodiment of a condition analyzing system 2.

### Detailed Description of Embodiments

In the following description similar features in different embodiments may be  
25 indicated by the same reference numerals.

**Fig. 1** shows a schematic block diagram of an embodiment of a condition analyzing system 2 according to an embodiment of the invention. Reference numeral 4 relates to a client location with a machine 6 having a movable part 8. The movable part may  
30 comprise bearings 7 and a shaft 8 which, when the machine is in operation, rotates. The operating condition of the shaft 8 or of a bearing 7 can be determined in response to vibrations emanating from the shaft and/or bearing when the shaft rotates. Additionally the operating condition of a bearing 7 can be determined in response to temperature measured on the casing of the machine. The client location

5 4, which may also be referred to as client part or user part, may for example be the premises of a paper mill plant, or some other manufacturing plant having machines with movable parts.

An embodiment of the condition analyzing system 2 is operative when a sensor 10 is  
10 firmly attached on or at a measuring point 12 on the body of the machine 6.

Although Figure 1 only illustrates two measuring points 12, it to be understood that a location 4 may comprise any number of measuring points 12. The condition analysis system 2 shown in Figure 1, comprises an analysis apparatus 14 for analysing the condition of a machine on the basis of measurement values delivered by the sensor  
15 10.

The analysis apparatus 14 has a communication port 16 for bi-directional data exchange. The communication port 16 is connectable to a communications network 18, e.g. via a data interface 19. The communications network 18 may be the world  
20 wide internet, also known as the Internet. The communications network 18 may also comprise a public switched telephone network.

A server computer 20 is connected to the communications network 18. The server 20 may comprise a database 22, user input/output interfaces 24 and data processing  
25 hardware 26, and a communications port 29. The server computer 20 is located on a location 28, which is geographically separate from the client location 4. The server location 28 may be in a first city, such as the Swedish capital Stockholm, and the client location may be in another city, such as Stuttgart, Germany or Detroit in Michigan, USA. Alternatively, the server location 28 may be in a first part of a town  
30 and the client location may be in another part of the same town. The server location 28 may also be referred to as supplier part 28, or supplier part location 28. A supplier company who may sell and deliver analysis apparatuses 14 occupies the supplier part location 28. The supplier company may also distribute use allowance to analysis

5 apparatuses 14 having use restricted condition monitoring functions, as discussed in further detail elsewhere in this document.

According to one embodiment of the system 2 the apparatus 14 is a portable apparatus which may be connected to the communications network 18 from time to  
10 time.

According to another embodiment of the system 2 the apparatus 14 is connected to the communications network 18 substantially continuously. Hence, the system 2 according to this embodiment may substantially always be "on line" available for  
15 communication with the supplier computer 20.

Fig. 2 is a schematic block diagram of an embodiment of a part of the condition analyzing system 2 shown in Fig 1. The condition analyzing system, as illustrated in Fig. 2, comprises a sensor unit 10 for producing a measured value. The measured  
20 value may be dependent on movement or, more precisely, dependent on vibrations. Alternatively the measured value may be dependent on temperature.

An embodiment of the condition analyzing system 2 is operative when a device 30 is firmly mounted on or at a measuring point on a machine 6. The device 30 mounted  
25 at the measuring point may be referred to as a stud 30. A stud 30 can comprise a connection coupling 32 to which the sensor unit 10 is removably attachable. The connection coupling 32 can, for example comprise double start threads for enabling the sensor unit to be mechanically engaged with the stud by means of a  $\frac{1}{4}$  turn rotation.

30

A measuring point 12 can comprise a threaded recess in the casing of the machine. A stud 30 may have a protruding part with threads corresponding to those of the recess for enabling the stud to be firmly attached to the measuring point by introduction into the recess like a bolt.

5

Alternatively, a measuring point can comprise a threaded recess in the casing of the machine, and the sensor unit 10 may comprise corresponding threads so that it can be directly introduced into the recess. Alternatively, the measuring point is marked on the casing of the machine only with a painted mark.

10

The machine 6 exemplified in Fig. 2 may have a rotating shaft with a certain shaft diameter  $d_1$ . The shaft in the machine 24 may rotate at a certain speed of rotation  $V_1$  when the machine 6 is in use.

15 The sensor unit 10 may be coupled to the apparatus 14 for analysing the condition of a machine. The analysis apparatus 14 comprises a sensor interface 40 for receiving a measured signal or measurement data, produced by the sensor 10. The sensor interface 40 is coupled to a data processing means 50 capable of controlling the operation of the analysis apparatus 14 in accordance with program code. The data  
20 processing means 50 is also coupled to a memory 60 for storing said program code.

25

According to an embodiment of the invention the sensor interface 40 comprises an input 42 for receiving an analog signal, the input 42 being connected to an analogue-to-digital (A/D) converter 44, the digital output of which is coupled to the to the data processing means 50.

30

The program memory 60 is preferably a non-volatile memory. The memory 60 may be a read/write memory, i.e. enabling both reading data from the memory and writing new data onto the memory 60. According to an embodiment the program  
memory 60 is embodied by a FLASH memory. The program memory 60 may  
comprise a first memory segment 70 for storing a first set of program code 80 which  
is executable so as to control the analysis apparatus 14 to perform basic operations  
(Figure 2 and Figure 3). The program memory may also comprise a second memory  
segment 90 for storing a second set of program code 100.

5

According to some embodiments of the invention the second set of program code is initially disabled so as to prohibit execution of said second set of program code. The disabled data 100 may be enabled in response to reception of a key.

- 10 According to an embodiment of the invention the apparatus 14 comprises an interface means for receiving the key.

The data processing means 50 is also coupled to a read/write memory 52 for data storage. Moreover, the data processing means 50 may be coupled to an analysis  
15 apparatus communications interface 54. The analysis apparatus communications interface 54 provides for bi-directional communication with a measuring point communication interface 56 which is attachable on, at or in the vicinity of the measuring point on the machine.

- 20 The measuring point 12 comprises a connection coupling 32, a readable and writeable information carrier 58, and a measuring point communication interface 56.

The writeable information carrier 58, and the measuring point communication interface 56 may be provided in a separate device 59 placed in the vicinity of the  
25 stud 30, as illustrated in Figure 2. Alternatively the writeable information carrier 58, and the measuring point communication interface 56 may be provided within the stud 30. This is described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

- 30 The sensor unit 10 comprises a vibration transducer, the sensor unit being structured to physically engage the connection coupling of the measuring point so that vibrations of the machine at the measuring point are transferred to the vibration transducer.

- 5 The analysis apparatus 14 comprises an analog-to-digital converter 44 electrically connected to receive an output delivered by the sensor unit 10, a microprocessor 50 electrically connected to receive an output of the analog-to-digital converter, and an analysis apparatus communication interface 54 connected to the microprocessor.
- 10 The system 2 is arranged to allow bidirectional communication between the measuring point communication interface 56 and the analysis apparatus communication interface 54. The measuring point communication interface 56 and the analysis apparatus communication interface 54 are preferably constructed to allow wireless communication. According to an embodiment the measuring point communication interface and the analysis apparatus communication interface are
- 15 constructed to communicate with one another by radio frequency (RF) signals. This embodiment includes an antenna in the measuring point communication interface 56 and another antenna the analysis apparatus communication interface 54.
- 20 Embodiments of the measuring point 12 and the communications interfaces 54/56 are described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

**Figure 3** is a simplified illustration of an embodiment of the memory 60 and its

25 contents. The simplified illustration is intended to convey understanding of the general idea of storing different program functions in memory 60, and it is not necessarily a correct technical teaching of the way in which a program would be stored in a real memory circuit. The first memory segment 70 stores program code for controlling the analysis apparatus 14 to perform basic operations. Although the

30 simplified illustration of Figure 3 shows pseudo code, it is to be understood that the program code 80 may be constituted by machine code, or any level program code that can be executed or interpreted by the data processing means 50 (Fig.2).

5 The second memory segment 90, illustrated in Figure 3, stores a second set of program code 100. The program code in segment 90, when run on the data processing means 50, will cause the analysis apparatus 14 to perform an added function. The added function may comprise an advanced mathematical processing of a measured signal received via the sensor interface 40. The added function, however,  
10 will be enabled and available only if the corresponding key or keyword has been entered.

#### A keyword embodiment

15 According to an embodiment of the analysis apparatus 14 (Figure 2), the interface means comprises a user input interface 102, whereby an operator may introduce the key in the form of a code word, also referred to as keyword. According to this embodiment the first set of program code 80 in the apparatus 14 comprises a program routine for requesting a code word, and for determining whether a received  
20 code word is accepted. According to an embodiment the user input interface 102 comprises a set of buttons 104. An embodiment of the analysis apparatus 14 comprises a user output interface 106. The user output interface may comprise a display unit 106. The data processing means 50, when it runs a basic program function provided in the basic program code 80, provides for user interaction by  
25 means of the user input interface 102 and the display unit 106. The set of buttons 104 may be limited to a few buttons, such as for example five buttons, as illustrated in Figure 2, or nine buttons as illustrated in Figures 7 and 9. A central button 107 may be used for an ENTER or SELECT function, whereas other, more peripheral buttons may be used for moving a cursor on the display 106. In this manner it is to be  
30 understood that symbols and text, such as the above mentioned code word, may be entered into the apparatus 14 via the user interface. The display unit 106 may, for example, display a number of symbols, such as the letters of alphabet, while the cursor is movable on the display in response to user input so as to allow the user to input a code word and/or other information. Hence, a key for enabling a disabled



5 condition monitoring function, and/or for adding an amount of usage allowance to a use restricted condition monitoring function may be entered via the user interface 102, 106 in an advantageously user friendly manner.

The enabled, executable version 110 of the second set of program code 100 may  
10 comprise an analysis routine for processing measured signals or measurement data received on the input 40 from the sensor 10.

According to an embodiment of the invention the second set of program code 100 is disabled by means of encryption. Hence, according to this embodiment the second  
15 set of program code 100 is an encrypted set of data 100. The encrypted data 100 is decryptable. Decryption may be achieved by means of a decryption program routine, provided that a correct decryption key, e.g. in the form of a data word, is received. The decryption routine may be comprised in one of the basic functions 80, illustrated in Fig 3.

20 In the course of decrypting an encrypted set of data 100, the decrypted data 110 may be stored at a third memory location 112. When decrypted, the second set of program code is an executable version 110 of the second set of program code 100. Hence, the memory location 90 may store a disabled version of computer program code and,  
25 provided a correct key has been entered, the memory location 112 will provide access to an enabled version of that computer program code.

Although, in the above, enabling of program functions has been described in detail only for a single program function, it to be understood that a large number of  
30 analysis functions may be provided in a disabled state in the analysis apparatus 14.

The number of disabled program functions stored by the apparatus 14 may be in the range from one to twenty-five, or even more. This advantageously leads to a wide selection of functions, and the apparatus 14 may be sold at a competitive and

5 relatively low price in a version where only one or a few of the program functions are enabled. According to a preferred embodiment an enabled program function remains enabled for a limited amount of use such that when the limited amount of use has been consumed, the program function will automatically become disabled again. An additional amount of use of the program function can be added by means  
10 of a dedicated usage enabling procedure. Execution of the dedicated usage enabling procedure may require clearance by the distributor. This embodiment of the invention advantageously makes it possible to provide, on the market at a competitively low price, a condition analysis system comprising a wide variety of program functions so that users may obtain a very versatile instrument at low initial  
15 cost. The user may instead pay a certain amount of money for obtaining an additional amount of use of a selected program function.

According to an embodiment of the invention the apparatus 14 stores at least five different disabled program functions, when the apparatus is ready to be delivered to  
20 a customer. According to another embodiment the apparatus 14 stores at least fifteen different disabled program functions upon delivery to a customer. According to some embodiments at least two of the initially disabled program functions are, when enabled, for generating indications of the condition of a machine in response to measured vibrations. According to preferred embodiments at least half of the  
25 initially disabled program functions are, when enabled, for generating indications of the condition of a machine in response to measured vibrations.

Each one of the disabled functions can be individually enabled in dependence of a key. According to some embodiments of the invention each function is individually  
30 enabled dependent on a unique key word. According to an embodiment a group of program functions can be enabled in dependence of one single keyword.

#### A Mechanical Key Embodiment

5 According to another embodiment the interface means in the apparatus 14 comprises a receptor for receiving a mechanical key (not shown). According to this embodiment an operator may introduce the key in the form of a mechanical key for the purpose of enabling an additional analysis apparatus function. The receptor for receiving a key may comprise contact means operating to enable the disabled data  
10 100 on reception of the corresponding correct key. According to one version of this embodiment the correct mechanical key may be rotated to cause a contact device to close an electric contact coupled to the memory 60, thereby enabling the reading of a range of memory addresses. Following such a procedure, the data processing means 50 is capable of reading and executing the second set of program code 100 which is  
15 stored on said second memory segment 90, i.e. on said range of memory addresses.

## 20 A Procedure and a System Providing Tailored Functionality for Evaluating the Condition of a Machine

Analysis of a machine's vibration signature is valuable for reducing unscheduled down time, reducing downtime for repair, minimizing periodic disassembly of a  
25 machine for inspection and greatly reducing the probability of catastrophic and unexpected machine failure.

According to one embodiment of the invention, a manufacturer of condition monitoring systems may provide customers with a very versatile, yet non-expensive  
30 analysis apparatus 14. The analysis apparatus 14 according to this embodiment allows for "tailored" outfit of Machine Condition Monitoring functions (MCM functions), in accordance with the individual preference of each customer. Potential customers of condition monitoring apparatus range from maintenance personnel - spending all their professional time analysing the condition of machines with the use

- 5 of advanced analysis functions - to workshop personnel with a need to make an occasional control of a few machines.

The workshop personnel usually require only a few basic monitoring functions for detection of whether the condition of a machine is normal or abnormal. On detecting  
10 an abnormal condition, the workshop personnel may call for professional maintenance personnel to establish the exact nature of the problem, and for performing the necessary maintenance work. The professional maintenance personnel frequently needs and uses a broad range of evaluation functions making it possible to establish the nature of, and/or cause for, an abnormal machine condition.  
15 Hence, different users of an analysis apparatus 14 may pose very different demands on the function of the apparatus.

In order to satisfy this broad range of demands, an embodiment of the present condition analysis system advantageously includes an apparatus 14 having a plurality  
20 of disabled Machine Condition Monitoring functions, each one of which may be enabled and activated on demand. Such an apparatus 14 for monitoring the condition of a machine can comprise:

- at least one input 42 for receiving measurement data from a sensor 10 for surveying a measuring point 12 of the machine; and
- 25 data processing means 50 for processing condition data dependent on said measurement data; said data processing means comprising means for performing at least two condition monitoring functions F1, F2. At least one of said plurality of condition monitoring functions F1, F2 has a locked state and an unlocked state; said locked state prohibiting complete execution of said condition monitoring  
30 function; and said unlocked state allowing execution of said condition monitoring function. The apparatus 14 also comprises means 141 (Figure 4) for changing the state of a selected condition monitoring function F1, F2 between the locked state and the unlocked state.

5 This solution advantageously provides the analysis apparatus with an improved versatility. A manufacturer can manufacture the apparatus in a single fashion, and a supplier can sell the apparatus in several versions. More precisely, an apparatus having two individually lockable/unlockable functions can be provided in the following versions:

- 10           with only the first function F1 unlocked;  
            with only the second function F2 unlocked;  
            with the first function F1 and the second function F2 unlocked.

Hence, a supplier can offer the apparatus in three versions, and this allows for selling  
15 it at different price levels dependent on the functionality included. Each client is therefore provided with a choice as to which functions to choose.

The data processing means may comprise a large number of locked or disabled functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked.

20

**Figure 4** is a simplified illustration of a second embodiment of the memory 60 and its contents. As described above, the first memory segment 70 stores program code for controlling the analysis apparatus 14 to perform basic operations.

25 The second memory segment 90, illustrated in Figure 4, stores a second set of program code 100. The program code in segment 90, when run on the data processing means 50, will cause the analysis apparatus 14 to perform a first Machine Condition Monitoring function (MCM function) F1.

30 The memory 60 may also include a third memory segment 120, as illustrated in Figure 4, storing a third set of program code 130. The program code in segment 120, when run on the data processing means 50, will cause the analysis apparatus 14 to perform a second Machine Condition Monitoring function F2.

5 The memory 60 may comprise a large number of functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked as described elsewhere in this document.

Once a function F1, F2, F3... Fn has been enabled it may be individually activated on  
10 demand, e.g. by an operator, so that the program function causes the analysis apparatus to perform the tasks prescribed by the computer program function. The functions F1 and F2 have been described in Figure 4 as being stored on separate memory locations, for the purpose of simplifying the understanding of this embodiment of the invention. It is, however, to be understood that the functions F1,  
15 F2, F3... Fn may be stored in other manners.

Additionally, one function Fi, where i is a integer in the range 1..n, may use some, or all, of the program code for another function Fj, where j is an integer in the range 1..n. This means that one function Fi may use another function Fj as a sort of  
20 subroutine.

#### Examples of Machine Condition Monitoring functions

The condition monitoring functions F1, F2...Fn includes functions such as:  
vibration analysis, temperature analysis, shock pulse measuring, spectrum analysis of  
25 shock pulse measurement data, Fast Fourier Transformation of vibration measurement data, graphical presentation of condition data on a user interface, storage of condition data in a writeable information carrier on said machine, storage of condition data in a writeable information carrier in said apparatus, tachometering, imbalance detection, and misalignment detection.

30

According to an embodiment the apparatus 14 includes the following functions:

F1 = vibration analysis;

F2= temperature analysis,

F3= shock pulse measuring,

- 5 F4= spectrum analysis of shock pulse measurement data,  
F5= Fast Fourier Transformation of vibration measurement data,  
F6= graphical presentation of condition data on a user interface,  
F7= storage of condition data in a writeable information carrier on said machine,  
F8= storage of condition data in a writeable information carrier 52 in said apparatus,  
10 F9= tachometering,  
F10= imbalance detection, and  
F11= misalignment detection.  
F12= Retrieval of condition data from a writeable information carrier 58 on said machine.
- 15 F13 = Performing vibration analysis function F1 and performing function F12 "Retrieval of condition data from a writeable information carrier 58 on said machine" so as to enable a comparison or trending based on current vibration measurement data and historical vibration measurement data.
- F14 = Performing temperature analysis F2; and performing function "Retrieval of  
20 condition data from a writeable information carrier 58 on said machine" so as to enable a comparison or trending based on current temperature measurement data and historical temperature measurement data.
- F15= Retrieval of identification data from a writeable information carrier 58 on said machine.

25

Embodiments of the function F7 "storage of condition data in a writeable information carrier on said machine", and F13 vibration analysis and retrieval of condition data is described in more detail in WO 98/01831, the content of which is hereby incorporated by reference.

30

The vibration analysis function F1 and shock pulse measuring F3 for the evaluation of the condition of a machine may comprise the step of obtaining a condition value by performing a measurement at the measuring point, such that the condition value is dependent on the actual condition of the machine. According to embodiments, the

5 routines F1 and F3 may comprise the step of the microprocessor 50 requesting measured values from the sensor unit 10 (Fig 2). According to one embodiment of the invention the sensor unit comprises a transducer having a piezo-electric element. When the measuring point 12 vibrates, the sensor unit 10, or at least a part of it, also vibrates and the transducer then produces an electrical signal of which the frequency  
10 and amplitude depend on the mechanical vibration frequency and the vibration amplitude of the measuring point 12, respectively. The electrical signal is delivered to the analog-to-digital converter 44, which with a certain sampling frequency  $f_s$  converts the analog signal to consecutive digital words in a known way. The microcomputer 50 stores a series of digital words, which correspond to a time  
15 sequence of the electrical signal in the memory 60, and then performs an analysis of the signal sequence, whereby the frequency and amplitude of the signal may be determined. Consequently, a measured value for the vibration amplitude  $A_v$  and the vibration frequency  $f_v$  may be determined.

20 According to an embodiment of the above mentioned function F7 "storage of condition data in a writeable information carrier on said machine", one or both of the values vibration amplitude  $A_v$  and/or vibration frequency  $f_v$  are delivered to the communications interface 54 (Fig 2). The microcomputer 50, delivers data to the communications interface 54 for the purpose of transmitting such data to the  
25 readable and writeable information carrier 58. This may be achieved by means of the communications interfaces 54 and 56, as described above in connection with Figure 2.

The above mentioned function F12 "Retrieval of condition data from a writeable  
30 information carrier 58 on said machine" comprises: acquiring a value indicating the condition of the machine at an earlier point of time from an information carrier 58 which is placed on, at or in the vicinity of the measuring point 12.



5 The above mentioned function F13 includes a combination of the above described functions F1 and F12. Hence function F13 includes "Performing vibration analysis" and performing "Retrieval of condition data from a writeable information carrier 58 on said machine" so as to enable a comparison or trending based on current vibration measurement data and historical vibration measurement data. An embodiment of  
10 function F13 comprises the steps of:

producing an actual condition value, said value being dependent on the actual condition at the measuring point, and

acquiring a stored value, indicating the condition of the machine at an earlier point of time from an information carrier 58 which is placed on the machine 6.

15 The function F13 may also include presentation of the actual condition value and the stored value on the display 106 for indication of changes. Also, a plurality of stored condition values may be acquired, wherein each condition value is associated with a time and/or date so that trends may be presented on the display.

20 When the apparatus 14 executes the function F15 "Retrieval of identification data from a writeable information carrier 58 on said machine" it obtains information indicative of the current machine and the current measuring point. Such identification data may be used for storage and retrieval of data in a data base in the memory 52. Such a data base may include stored condition values wherein each  
25 condition value is associated with a time and/or date. The retrieved identification data may be used for fetching the relevant previously stored data relating to the current measuring point.

An embodiment of the function F15 "Retrieval of identification data from a  
30 writeable information carrier 58 on said machine" may include the data processor 50 retrieving interpretation information relating to the measuring point. The interpretation information may include technical type values such as a diameter value d1 and a rotational speed value V1 relating to a rotating shaft in the machine.

5 An embodiment of the function F12 "Retrieval of condition data from a writeable information carrier 58 on said machine" also includes retrieving interpretation information relating to the measuring point. With knowledge of the interpretation information d1 and V1, respectively, a measured vibration can be converted to an actual condition value Ka. A predetermined interpretation algorithm is stored in the  
10 memory 60, and starting from an amplitude value Av and interpretation information, such as d1 and V1, the micro-computer produces a corresponding condition value Ka dependent thereon. Such an interpretation algorithm is based on an embodiment of a method for producing a condition value described in the Swedish Laid-Open Document 339 576.

15

According to one embodiment, the interpretation algorithm is based on the machine classification standard ISO 2954.

20

According to preferred embodiments the apparatus 14 does not have any function for establishing whether steam leaks or not from a steam trap.

25

30

According to an embodiment of the invention the apparatus 14 includes a function for statically aligning a first shaft with a second shaft. According to an embodiment a function F16 for aligning a first shaft with a second shaft can be performed by  
connecting a first dual-axis position sensing detector providing a first signal and a second dual-axis position sensing detector providing a second signal to port 16 of the analysis apparatus (Figure 2, Figure 12). When executing the function F16 for aligning shafts, the user interface 106 of apparatus 14 operates to provide readout means having defined alignment conditions and being responsive to the first signal  
and the second signal for visually displaying shaft alignment, whereby with adjustment of the first shaft with respect to the second shaft, alignment of the first shaft with the second shaft will be indicated on the readout means according to the defined alignment conditions. In order to perform the alignment function an alignment detection device comprising the first dual-axis position sensing detector

5 for generating the first signal and the second dual-axis position sensing detector for  
generating the second signal is connected to port 16. The alignment detection device  
also comprises first mount means for mounting the first dual-axis position sensing  
detector to the first shaft;  
second mount means for mounting the second dual-axis position sensing detector to  
10 the second shaft;  
a first alignment radiation source mounted on the first mount means and oriented to  
provide a first alignment radiation beam to the second dual-axis position sensing  
detector to generate the second signal; and  
a second alignment radiation source mounted on the second mount means and  
15 oriented to provide a second alignment radiation beam to the first dual-axis position  
sensing detector to generate the first signal. According to an embodiment of the  
invention, the apparatus 14, when executing the alignment function in co-operation  
with the alignment detection device, operates as disclosed in US 4,518,855, the  
content of which is hereby incorporated by reference.

20

According to an embodiment of the invention the apparatus 14 also includes a  
function F17 for balancing a rotating shaft. Also a device to be balanced can be  
attached to an already balanced shaft of a machine, and thereafter the apparatus 14,  
25 when executing the function F17 for balancing, will operate to provide information  
about the position and weight of the balancing weight(s) needed to counteract an  
imbalance of the rotating device. The apparatus 14, when executing a version of the  
function F17 for balancing, will operate to provide information about weight to be  
removed from the device-to-be-balanced in order to counteract an imbalance and  
30 information about the position where that weight needs to be removed. Removal of  
weight can be achieved, e.g. by drilling.

#### A Usage Debiting/Crediting Procedure

5

Figure 5 is a flow chart illustrating an embodiment of a procedure according to the invention. An operator planning to perform a round of measurements may first consider what type of measurements and analysis is to be done, i.e. what type of Machine Condition Monitoring function is required. The choice of Machine

10 Condition Monitoring function depends on the type of machinery to be inspected, and on how advanced an evaluation the operator intends to achieve, as described above.

A user help function, provided among the basic functions 80 in the first memory segment 70, can be activated by the operator to provide information about the

15 purpose of any individual function F1 - Fn. This can advantageously contribute to a stepwise increase of the competence of the operator, since the operator may start using relatively simple MCM functions and then, being informed by the user help function, the operator may choose to proceed to using more advanced functions.

20

Once the operator has decided that he will need to enable a presently disabled function from the group consisting of functions F1-Fn the operator may activate the Usage Debiting/Crediting Routine 132 (Fig. 4). The Usage Debiting/Crediting Routine 132 can also be used for changing the value of a level parameter. The value

25 of the level parameter decides the extent to which the analysis apparatus 14 may be used, as described in further detail below.

The Usage Debiting/Crediting Routine 132 (Fig. 4) is one of the basic functions 80 in the first memory segment 70, which is described in connection with Fig 4 above.

30

By means of the user interface 102,106 (Figure 2) the operator can activate the Usage Debiting/Crediting Routine, as illustrated by step S110 in Fig.5.

5 In step S120 (Fig 5), the Usage Debiting/Crediting Routine 132 causes the apparatus 14 to display a list of the available functions, e.g. via the user interface 102/106 (Figure 2). This may include a listing of a plurality of different functions and an indication about status for each individual function. According to a preferred embodiment the status information indicates for each function whether it is disabled  
10 or enabled. For the enabled functions the status information may also include information about the remaining amount of use for the associated function. The remaining amount of use for the associated function is indicated by variables Use\_F1 and Use\_F2, respectively, for the functions illustrated in Figure 4. As illustrated in Figure 4, there may be a status field 142 associated with each function F1, F2, F3...  
15 Fn, the status field 142 comprising information about whether it is disabled or enabled and, when enabled, information about the remaining amount of use for the associated function. According to this embodiment the level parameter may be a counter value, herein referred to as "Use\_F<sub>k</sub>", where k is an integer indicating the association with the corresponding function F1, F2, F3... Fn. Hence, function F1 is  
20 associated with level parameter "Use\_F<sub>1</sub>", and function F2 is associated with level parameter "Use\_F<sub>2</sub>" etc.

In step S130 the operator selects to buy more usage of a function. In response thereto a request for an additional amount of usage is generated (S140).

25 According to an embodiment the request includes information identifying the function whose usage is to be increased, and payment information. The payment information identifies a person responsible for paying the cost of the requested usage or, alternatively the payment information can in itself effect payment. The payment  
30 information may include data such as a credit card number. According to another embodiment the payment information may include information indicating that payment has already been effected.

- 5 According to an embodiment, the above mentioned request includes information identifying the individual analysis apparatus, and the function whose usage is to be increased, and payment information.

The request is delivered to the premises 28 of a supplier (S150). According to an  
10 embodiment the request is delivered by means of the communications network 18 (Fig 1). Hence, request may be delivered from the apparatus 14 to the server computer 20, e.g. via data communication.

At the supplier premises 28 the request is processed (S160), the processing including  
15 a verification step for establishing whether the request is to be granted or not. The verification may, for example, include an evaluation of the payment information to decide whether the payment information satisfies certain predetermined payment criteria. According to a preferred embodiment the request is processed automatically by the server computer 20.

20 According to an embodiment this payment information evaluation includes a step of checking whether the payment information indicates that payment has already been effected, or whether it merely indicates a person responsible for paying the cost. If the payment information merely indicates a person responsible for paying the cost,  
25 the server computer 20 may proceed to check with a dedicated database for establishing whether clearance may be given for this person. The dedicated database may include information about the financial situation for the person responsible for paying the cost. According to one embodiment, the server computer limits this clearance check to a verification using data in the database 22 internal to the  
30 premises of the supplier 28. According to another embodiment the payment evaluation includes a communication with a financial services database.

Step S170 illustrates that if step S160 results in the request being granted, the supplier will deliver a key to the client (S180). If, on the other hand, the request is

5 not granted, the supplier computer 20 will generate a Request\_denied-message. The Request\_denied-message may be delivered to a supplier sales person (not shown) for the purpose of alerting the supplier about a failed attempt buy function usage.

According to an embodiment, a Request\_denied-message is also sent to client part 4 (See figure 1) for causing the apparatus 14 to display information to the effect that  
10 the request was denied. The Request\_denied-message may include information indicative of the reason for denial of the request, as well as a copy of the original request message, as described in step S140 above.

In step S190 the key is received in the apparatus. The reception of a key may be  
15 achieved via the user interface 102,104,106, 182 (See Figures 2, 7, 9, 12 and 15). Alternatively the key may be received via port 16.

After reception, there is a verification procedure S200 for ascertaining the validity of the key. The result of the verification procedure S200 is an acceptance or a  
20 discarding of the key. If the key is not accepted, the apparatus will provide a non-acceptance indication by means of the user interface 106 (Step S210).

If the key is accepted the apparatus 14 will, in response to the key, amend (step S220) a level parameter "Use\_F<sub>k</sub>" to change an amount of usage status and/or the  
25 enabled/disabled parameter 143 for the selected function.

According to an embodiment, the key is associated with the selected function so that, when correctly applied to the apparatus 14, the key will increase the allowed amount of usage of that function. In other words, the key may cause a level parameter  
30 associated with the selected function to be amended. The level parameter associated with a selected function is a parameter whose purpose is to indicate how much the apparatus 14 may execute the selected function.

5 With reference to Fig 4, an embodiment of the invention involving a level parameter is described. According to this embodiment the level parameter may be a counter value, herein referred to as "Use\_F<sub>k</sub>", where k is an integer indicating the association with the corresponding function F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>... F<sub>n</sub>. Hence, function F<sub>1</sub> is associated with level parameter "Use\_F<sub>1</sub>", and function F<sub>2</sub> is associated with level parameter  
10 "Use\_F<sub>2</sub>" etc. According to this embodiment, the key will include a first data portion for associating the key with the corresponding function F<sub>1</sub>, F<sub>2</sub> or F<sub>3</sub> etc; and a second data portion for indicating the amount of use purchased.

After execution of step S220, the user interface of the apparatus will present  
15 information (step S230) for the purpose of allowing the operator to select a next operation to be executed. This includes selecting between e.g. starting a measurement, returning to step S110 for repeating the above procedure, or turning off the apparatus 14.

#### 20 Example 1

**Figure 5C** is a simplified illustration of a principle of an embodiment of an account value or amount of usage parameter for use in an apparatus wherein a user pays to get a number of credits, also referred to as "units of use". It is noted that in the Example 1 embodiment the computer program routine "Function\_F1" becomes  
25 disabled when the parameter Use\_F1 reaches a first reference value (zero in the example).

This example describes an embodiment relating to the above-mentioned procedure. When a client has purchased e.g. ten units of use for the computer program routine  
30 "Function\_F1" (See Fig. 4), the amount indication portion of the key may cause the parameter Use\_F1 to increase by ten units. Hence, if the parameter Use\_F1 had a numerical value zero (0) before reception of the key, then the parameter Use\_F1 will have numerical value "10" (ten) after correct reception of that key. For each execution of the computer program routine "Function\_F1" the numerical value of the



5 parameter Use\_F1 will be decreased by one (1). When the computer program routine "Function\_F1" has been executed ten times so that the parameter Use\_F1 again has the numerical value zero (0), the computer program routine "Function\_F1" will become disabled.

In order to enable the computer program routine "Function\_F1", the client can  
10 purchase a new amount of use by means of the procedure described above.

### Example 2

This example describes an embodiment similar to the Example 1 embodiment above.  
15 According to example 2, the cost per use changes after a certain level of use has been attained. A user can enter a number  $A_p$  of credits or units of use for a selected function, such as function F1, by means of entering a key. When the function F1 is executed by the apparatus 14 the use of the condition monitoring function F1 will be registered by deducting e.g. one credit for each execution. However, the method may  
20 also include the steps of:

- reading a current value of said registered use;
- comparing said current value with a second reference value;
- registering use at a first rate when said current value is above the second reference value; and

25 registering use at a second rate when said current value is below the second reference value.

This advantageously enables a supplier to sell usage at different costs. When, according to one embodiment, a user has paid for a certain amount  $A_p$  of usage, the  
30 second reference value is a level indicating that the amount  $A_p$  of usage already paid for has been spent. This means that any further use will be usage which has not yet been paid for. By the feature of registering such further use at a second rate it is possible to charge a higher cost per unit of usage for such further use. Accordingly,

- 5 one execution of the function F1, when registered at the second rate, may result in a deduction of two credits.

Figure 5D is an illustration of Example 2. A user, when entering a number  $A_p$  of credits or units of use for a selected function, such as function F1, by means of entering a key for the first time, will get  $A_p$  credits that will be deducted at the first rate. Assuming that the user has bought ten credits ( $A_p = 10$ ), the parameter Use\_F1 will assume the value 10. Hence, if the first rate is deduction of one credit per execution of function F1, the parameter Use\_F1 will assume the value zero ("0") after ten executions of function F1. When the value zero ("0") is the second reference value, any further execution of the function F1 will be registered at the second rate, e.g. two credits per execution. Hence, the user will advantageously still be able to use the function F1, although this use has not yet been paid.

If the first reference value is -4, as illustrated in Figure 5D, the apparatus will allow the function F1 to be executed twice before the parameter Use\_F1 assumes the first reference value "minus four" (-4). When the parameter Use\_F1 assumes the first reference value, the computer program routine "Function\_F1" will become disabled.

However, next time that the user enters a key indicating a value of ten credits, the parameter Use\_F1 will assume the value six, since it starts from a negative value:

$$-4 + 10 = 6$$

The above example values of first and second reference values are merely examples. Of course, the number of credits, and the reference values may have other values without departing from the inventive concept described herein. Additionally, the amount of use may be counted as duration of time, the first and second reference values also being indicative of time duration. For example a user may buy allowance to use a selected function for a first total period, e.g. sixty hours, the second

- 5 reference value being indicative of a time when the charge rate is to be changed, and the first reference value being indicative of a when disabling occurs.

### An Embodiment of a Usage Registering Procedure

10

Figure 6 is a flow chart illustrating an embodiment of a procedure according to the invention.

- The procedure may start with step S230, i.e. the user interface of the apparatus  
15 presents information for the purpose of allowing the operator to select a next operation to be executed.

- In step S240 the operator selects to request the apparatus to perform a Condition analysis function. This means that the operator may select one of the functions  
20 whose use is to be registered. The operator may do this by means of the user interface 102,106.

- In a step S250 (Figure 6) the computer program 80 (Figure 4) will in response to the operator input check whether the selected operation involves any of the of the  
25 functions whose use is to be registered. The functions whose use is to be registered includes the above discussed MCM functions F1 - Fn. A function whose use is to be registered is referred to as a "restricted function" in the following text.

- If the selection involves only unrestricted functions the apparatus 14 (Fig2) will  
30 initiate and perform such operation (step S260) and then return to step S230.

If a restricted function is selected, the computer program 80 (Figure 4) will in response thereto check whether the selected function is enabled or disabled (Step S270).

- 5 If the selected function is disabled, the computer program 80 will present information to this effect (S280), and offer to proceed to any of steps S230, step S110 or S120, described above. According to an embodiment, the program 80 will offer to proceed with step S470 in the procedure described in Figure 14.
- 10 If the selected function is enabled, the computer program 80 will register the use of the selected restricted function (S290), and execute the selected restricted function (Step S300). Although Fig. 6 illustrates a certain order between activities, it to be understood that the invention is not restricted to performing the steps in that particular order. In particular, the registration of use (step S290) may be performed
- 15 before or after or sometime during the execution of the restricted function.

According to a preferred embodiment the use is registered by changing the value of a counter parameter Use\_F<sub>k</sub>. The index k in "Use\_F<sub>k</sub>" indicates association to function F<sub>k</sub>. When the parameter Use\_F<sub>k</sub> has a value 100, this may indicate that one hundred

20 units of use remains. One unit of use may correspond to one complete execution of the function F<sub>k</sub>. Hence, according to an embodiment, the counter parameter Use\_F<sub>k</sub> can correspond to the number of times the function F<sub>k</sub> may be used before all the allowed use has been spent. With reference to Figure 4 step S290 may therefore include amending the parameter Use\_F<sub>k</sub> in status field 142 for the selected function

25 to update the information indicating the remaining amount of use.

After successful execution and registration of use the computer program 80 may update a status register or status field 142 (step S310). Such update may include updating any and all variables/parameters needed for delivering status information

30 correctly next time step S120 is performed (See Fig 5 and corresponding description). Hence, step S310 may include detection of a usage parameter value Use\_F<sub>k</sub> indicating that a certain act is to be performed in response to the changed status. For example, if a parameter indicates that all usage for one or all restricted functions has been spent, the said certain act may include disabling the restricted

5 function or functions. Such disabling may include erasing a decrypted version 110, so that only encrypted versions remain.

**Figure 7** is a physical embodiment of an apparatus 14. The apparatus has an apparatus body; and a display 106 provided on at least one surface of said apparatus  
10 body. Also provided on the body is a user input interface 102 comprising a key board 103.

The apparatus body is portable; and it is shaped and adapted to enable a one-hand grip, as illustrated in figure 9. **Figure 9** illustrates the apparatus 14 being gripped by  
15 a hand 140 of a user. Moreover the user input interface 102 is positioned and adapted so as to enable user interaction by means of the user hand 140. In the embodiment shown in Fig 9 the user input interface 102 is operable by means of a thumb 150 of the user.

20 **Figure 8** is a side view of the apparatus shown in Figure 7. The apparatus body is provided with fasteners 160 for a wrist strap 170. The wrist strap 170 is illustrated in Figure 9.

The body also has a holder 180 for an elongated device. The elongated device may  
25 be a pen or a pointing device for user input via the display 106. The display 106 may be a touch sensitive display allowing user input by means of the pointing device. The display 106 therefore includes a display area which is provided with touch sensors 182, also referred to as a touch screen 182, co-operating with a touch input interpreter. Hence, the display may comprise an LCD unit, for displaying images and  
30 text, having integrated touch sensor means for detecting user input via the display area.

The provision of touch sensors 182 for receiving user input via the area of the display 106 provides for an improved user interaction. For example, as described

5 above, the function F13 may include presentation of an actual condition value and a plurality of stored condition values so that trends may be presented on the display 106, wherein each condition value is associated with a time and/or date. When such a trend is displayed, for example in the form of a curve indicating the temporal progression of the condition of the machine, the user may touch the screen at an  
10 interesting part of the curve for the purpose of obtaining information associated with that part of the curve. In response to such user interaction the apparatus may therefore display e.g. the time and date information associated with that part of the curve.

15 **Figure 12** is a block diagram of an embodiment of the apparatus 14 shown in Figure 1 and/or figures 7 and 8. The apparatus according to the Figure 12 embodiment may comprise a memory 60 having a plurality of program functions F1, F2, F3... Fn, where n is a positive integer. Each one of the functions F1, F2, F3... Fn may be individually enabled/unlocked or disabled/locked.

20 The memory 60 includes program functions for causing the data processing means 50 to perform the methods described with reference to Figures 5 and 6. Hence, the memory 60 includes a program function 140 (Figure 4) for registering use of any of the functions F1, F2, F3... Fn. The program function 140 may be referred to as a  
25 logger, which operates to update the above mentioned use parameters Use\_Fk.

Moreover, the memory 60 also includes a program function 141 for changing the state of an individual selected condition monitoring program function between an enabled state and a disabled state. The state control function 141 may operate to read  
30 the parameters Use\_Fk, as described in connection with step S310 in Figure 6 above. The state control function 141 may operate to disable a function Fk in response to the outcome of a comparison between a parameter Use\_Fk and a first reference value Rk. The first reference value Rk is a reference value indicative of a limit. The

- 5 state control function is adapted to disable function F<sub>k</sub> when the parameter Use\_F<sub>k</sub> reaches the first reference value R<sub>k</sub>.

The apparatus 14 includes data processing means 50 in the form of a central processing unit (CPU) 50A co-operating with a Field Programmable Gate Array circuit (FPGA) 50B. According to an embodiment the central processing unit 50A  
10 operates to execute the basic functions 80, such as the program functions for causing execution of the methods described with reference to Figures 5 and 6. The Field Programmable Gate Array circuit 50B is programmable to execute the functions F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>... ..F<sub>k</sub>... ..F<sub>n</sub>. In effect, the CPU 50A, in response to the basic program  
15 functions 80 and user input, operates to control the operation of the FPGA 50B. The CPU 50A may, for example, control which of the functions F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>... ..F<sub>k</sub>... ..F<sub>n</sub> are to be executed by the Field Programmable Gate Array circuit 50B.

The Field Programmable Gate Array circuit 50B advantageously provides a  
20 combination of flexibility and very high performance to the apparatus 14 in that the functions executed by the FPGA may be software controlled and the FPGA allows for truly parallel processing. Hence, a large amount of data can be processed relatively fast by means of the FPGA. This solution advantageously enables simultaneous execution of two, three or more of the condition monitoring functions  
25 F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>... ..F<sub>k</sub>... ..F<sub>n</sub>. The apparatus 14 is highly versatile and flexible in that it can be upgraded to perform new functions simply by adding or changing a program. Hence a new or different condition monitoring function can be added to the apparatus 14 by a simple upgrade of the programs in memory 60 (Figure 2, figure 3, figure 4, figure 12). When the changed program runs on the FPGA the new function  
30 can be executed without necessarily changing any of the hardware in the apparatus 14.

Moreover, the FPGA provides a large processing capability in relation to the amount of space it requires. The FPGA may be mounted on a circuit board, where it requires

5 a small surface in relation to the large processing capability it provides. According to an estimate, the amount of surface saved on a circuit board by using an FPGA exceeds 25 %. In other words, the volume of the apparatus 14 can be significantly reduced while the data processing capability is maintained or increased as a result of using an FPGA circuit in the apparatus 14. Therefore the choice of FPGA  
10 contributes to enable the provision of a portable instrument satisfying the conflicting requirements of having a large processing capability and a compact instrument which makes it easier to carry for the user.

Additionally the FPGA has a low power consumption as compared to traditional  
15 logic circuits as well as when compared to traditional data processors.

The FPGA 50B is coupled to receive digital Shock Pulse Measurement data from an A/D-converter 44A, which is coupled to an input 42A for an analogue Shock Pulse Measurement signal (SPM signal). The FPGA 50B is also coupled to receive digital  
20 temperature data from an A/D-converter 44B, which is coupled to an input 42B for an analogue temperature measurement signal. The FPGA 50B is also coupled to receive digital vibration data from an A/D-converter 44C, which is coupled to an input 42C for an analogue vibration measurement signal. Moreover the FPGA 50B is coupled to receive digital data from an A/D-converter 44E, which is coupled to an  
25 input 42E for an analogue measurement signal indicative of a measured electric voltage or a measured electric current. The FPGA 50B is also coupled to an input 42D for receiving binary tachometering measurement signals.

The FPGA 50B is also coupled to a communications interface 54 for bi-directional  
30 communication with a device 59 on a machine 6, as described in connection with Figure 2.

Moreover the apparatus 14 includes a user interface 102. The user interface 102 includes a display 106 having touch sensors 182 for associating information



5 displayed at a certain position of the display area with user activation of the sensor at said certain position. In the block diagram of Figure 12 the touch sensor 182 is illustrated as a block separated from the display 106. In a physical embodiment, however, the touch sensors 182 are integrated with the display area 106, as illustrated in Figure 7, such that the touch sensors 182 detect user interaction with  
10 the display area 106.

The CPU 50A is coupled to a data port 16 as described in connection with Figure 1, for enabling communication with a supplier computer 20.

15 The apparatus 14 also includes clock functionality 210 for providing time and date information. This is useful for generating a time stamp, e.g. when a condition value has been produced, and the value is to be stored for future retrieval. Additionally, the time and date information may be used for controlling the enabling and disabling of functions F1, F2, F3... ..Fk... ..Fn. According to an embodiment, the apparatus 14  
20 may receive, via port 16, a key comprising a code for enabling a selected function from a first predetermined date, such as e.g. March 1, 2003, until a second date such as April 15 2003. Such a key may include a data portion indicative of the identity of the analysis apparatus, a data portion indicative of the function to be enabled, a data portion indicative of the first date and a code portion indicative of the second date.

25

Alternatively the key may cause a selected function to be enabled for a certain duration starting from a certain date.

According to an embodiment the apparatus comprises a logger operating to register  
30 the amount of use for one, some or all condition monitoring functions, as described above. This may be done by counting the number of executions of the restricted functions, as described above. According to an embodiment a Reporting function is provided, among the Basic Program Functions 80 (Fig. 3 & 4), for causing the apparatus 14 to deliver a report about the accumulated registered use. The reporting

5 function is adapted to deliver such a report with a certain periodicity. For example, the Reporting function may be set to deliver a report no less than once every 30 days. The reporting function is set to deliver the report via the port 16 for transmission to the supplier computer 20 via the communications network 18 (Fig 1). Upon reception of the report, the supplier computer may be adapted to cause an output to  
10 the supplier indicative of the amount of use accumulated for that particular analysis apparatus. Alternatively the supplier computer may be arranged to automatically generate an invoice with a certain regularity, such as no less than once every 30 days, the invoice thereafter being delivered to a user associated to the analysis apparatus. For this purpose the usage report may include data indicative the identity of the user.  
15 This may be achieved by providing unique identities for each analysis apparatus, and keeping, at the supplier, a data base 22 associating each unique analysis apparatus identity with a corresponding client/user. The reporting function co-operates with the timer functionality 210 such that if no usage report has been transmitted at the expiration of the certain period, the timer co-operates with the State control function  
20 141 to disable one, several or all the restricted functions F1, F2, F3... ..Fk... ..Fn. According to another embodiment the apparatus 14 expects to receive a receipt from the supplier part 20, 28 after sending a usage report. The receipt should include information, preferably in a coded manner, indicating that the usage report has been received by the supplier part 20, 28. If no receipt has been received within a first  
25 time period the apparatus will provide a warning to the user by means of the user interface 106. If no receipt has been received within a longer, second time period the apparatus will disable one, several or all the restricted functions F1, F2, F3... ..Fk... ..Fn.

30 **Fig. 15** shows a schematic block diagram of another embodiment of a condition analyzing system 2. According to the Figure 15 embodiment the client part 4 comprises an apparatus 14, and a separate client computer 300. The client computer 300 may be connectable to a communications network 18, e.g. via a data interface 19. The communications network 18 may be the world wide internet, also known as the

- 5 Internet. The communications network 18 may also comprise a public switched telephone network. The supplier part may be able to exchange information with the computer 300 via the communications network 18, e.g. in the manners discussed above in connection with Figure 1.
- 10 According to an embodiment the apparatus 14 is connectable to the computer 300 via port 16, for exchanging information relating to usage. According to a preferred embodiment the apparatus 14 is capable of delivering the above mentioned usage report to the supplier via the computer 300. According to an embodiment
- 15 information exchange between the apparatus 14 and the computer 300 may be achieved by transfer of a writeable memory device connectable to the computer 300 as well as to the apparatus 14. Information exchanged in this manner may include the above mentioned usage report, and/or the above mentioned receipt indicating to the apparatus 14 that the usage report has been received by the supplier part 20, 28. The coded information in the receipt may also be read by a user from the user interface of
- 20 computer 300, and input into the apparatus 14 by means of user interface 106, 182, 103.

Figure 13A illustrates a part of memory 60 comprising a function  $F_k$  and an associated status field 142. The status field 142 includes a segment 143 for data

25 indicative of the state of the associated function: enabled or disabled. The status field 142 also includes a segment 144 having data indicative of the cost  $C_{fk}$  for executing the associated function  $F_k$ . For example, function  $F_1$  may have a cost value  $C_{fk} = 1$  charging unit per execution, and function  $F_3$  may have a cost value  $C_{fk} = 3$  charging units per execution. In another example, function  $F_1$  may have a cost value  $C_{fk} = 1$

30 charging unit per unit of time, whereas function  $F_3$  may have a cost value  $C_{fk} = 3$  charging units per unit of time. Hence, different functions may be charged at different cost rates, by providing a certain exchange rate between one charging unit and a certain monetary currency. For example one charging unit may correspond to

- 5 x US cents, where x is a number such as 10, 15, 50, 100, 1000 or another number dependent on what price is suitable.

An alternative embodiment for registering use, i.e. an embodiment of step S290 in Figure 6, is as follows: The use may be registered by counting a duration of execution of a restricted function, in which case the registration of use may include a  
10 registration of a start time in a step S290A (as indicated in Fig 6) and the registration of a stop time in a step S290B. In such an embodiment the step S290A may be performed immediately before the execution of the restricted function, and the step S290B is executed immediately thereafter. According to this embodiment the  
15 parameter Use\_ $F_k$  may be indicative of a total duration of time the function  $F_k$  has been activated. Figure 13B illustrates a part of memory 60 according to this embodiment, comprising a function  $F_k$  and an associated status field 142 $_k$ . The parameter Use\_ $F_k$ , indicative of an accumulated total duration of active time for the function  $F_k$ , is stored by the logger in a segment 220 $_k$  in status field 142 $_k$ . A  
20 reference duration value is stored in segment 230 $_k$ , and a cost factor may be stored in a segment 240 $_k$ . The reference duration value is set by reception of a key, and it indicates an amount of use that has been paid for. According to this embodiment the state control function may be arranged to disable Function  $F_k$  when the parameter Use\_ $F_k$  in segment 220 is equal to the reference duration value in segment 230 $_k$ .  
25 Different charges per time unit for different functions  $F_k$ ,  $F_i$  may be obtained by a multiplying the duration of execution of a restricted function  $F_k$  with a cost factor  $C_k$ , and multiplying the duration of execution of another restricted function  $F_i$  with a different cost factor  $C_i$ . The cost factors for functions  $F_k$  and  $F_i$ , respectively, may be stored in a memory segments 240 $_k$  and 240 $_i$  respectively. In accordance with the  
30 same principle, different charges per execution for different functions  $F_k$ ,  $F_i$  may be obtained by a multiplying the number of executions of a restricted function  $F_k$  with a cost factor  $C_k$ , and multiplying the number of executions of another restricted function  $F_i$  with a different cost factor  $C_i$ . In this manner the mutually different functions  $F_k$ ,  $F_i$  can be charged at different costs per execution.

5

Another Embodiment of a Usage Debiting/Crediting Procedure

10 This embodiment differs from the Usage Debiting/Crediting Procedure described with relation to Figure 5 in that there is provided a centralized debit/credit account parameter 250 rather than separate accounts for each function. There is a plurality of restricted functions having individually settable states: either disabled or enabled. The enabling/disabling procedure is a separate procedure being performed in  
15 response to a state key associated with the selected function. There is a separate credit/debit key for allowing a supplier to amend the value of the centralized debit/credit account parameter 250.

According to this embodiment the request includes information identifying the  
20 individual analysis apparatus, and payment information. The key to be received may cause a level parameter associated with the use of all relevant functions in that individual analysis apparatus to be amended. Hence, such a level parameter may be associated with all MCM functions.

25 Whenever a client operator selects to use a restricted function, the amount of use is deducted from centralized debit/credit account 250. Only those functions which are in the enabled state can be activated for execution, provided the centralized debit/credit account parameter 250 has a value above a first reference value. The first reference value is a limit value, such that if an operator attempts to execute a  
30 restricted function when the value of the centralized debit/credit account parameter 250 is equal to, or exceeds the first reference value, then the registering routine causes the apparatus 14 to disable all restricted functions.

One version of this embodiment further comprises the steps of:

5 reading a current value of the centralized debit/credit account parameter  
250;

comparing said current value with a second reference value;

deducting credit units from the centralized debit/credit account  
parameter 250 at a first rate when said current value is above the second reference  
10 value; and

deducting credit units from the centralized debit/credit account  
parameter 250 at a second rate when said current value is below the second reference  
value.

This advantageously enables a supplier to sell usage at different costs. When,

15 according to one embodiment, a user has paid for a certain amount  $A_p$  of usage, the  
second reference value is a level indicating that the whole amount  $A_p$  of prepaid  
usage has been spent. This means that any further use will be usage which has not  
yet been paid for. By the feature of registering such further use at a second rate it is  
possible to charge a higher cost per unit of usage for such further use.

20 Moreover, the amount of use may be charged at different rates for different functions  
by means of individual cost factors ( $C_k$  and  $C_i$ , respectively) associated with each  
individual function, as described above and as illustrated in Figures 13A and 13B.

25 The centralized debit/credit account parameter 250 may be stored in a memory  
location 260 in the memory 60, as illustrated in Figure 4.

Figure-14 is a flow chart illustrating an embodiment of a procedure for delivering an  
apparatus 14, and for adding use or functionality by means of a key from the supplier  
30 part 28. The method also relates to an embodiment of a method for generating a  
request for such a key or code. Such a key/code may be used for amending the  
centralized debit/credit account parameter 250 and/or for enabling a disabled  
function. Step S610 in Figure 14 may include the procedure according to Figure 6,

- 5 starting e.g. with step S230. It is to be understood that Figure 14 focuses on certain mathematical or technical details that may also be used in the context of the procedure described in connection with Figure 5A and 5B above. The method may start at the supplier 28 (Figure 1, Figure 15) before delivery of the apparatus. In a step S410 a code  $k_i$  is set to a start value, which may be chosen to e.g. 0. Thereafter
- 10 identity information is entered. This may be a number identifying an individual apparatus 14, or information identifying an individual condition monitoring function or both. A new code  $K_{i+1}$  is generated in accordance with a first mathematical algorithm in dependence of the identity information and the previous code  $k_i$  (S430).
- 15 The variable  $K_i$  is updated to the value of the new code  $K_{i+1}$  (step S440). The updated value  $K_i$  is stored in the apparatus 14, and in the supplier database 22 (step S450). The copy stored in supplier database 22 is herein referred to as  $K_{i22}$ , and the copy stored in the apparatus 14 is herein referred to as  $K_{i14}$ .
- 20 The apparatus is delivered to a client/user (step S460). Thereafter the user may operate the apparatus as described in connection with Figures 5A, 5B and/or Figure 6.

At some point in time the user may want to buy additional use allowance. The user

25 may then cause the apparatus to generate a request  $U_R$  (Use Request) for additional Use allowance (step S470). Step S470 may be attained as described in connection with steps S130, S140 in Figure 5A. The request  $U_R$  is received in supplier computer 20 (step S480). In supplier computer 20 the code  $K_{i22}$  is retrieved from database 22. The code  $K_{i22}$  and the content of the request  $U_R$  are used in a predetermined

30 mathematical algorithm, and a checksum  $S_{c1}$  with a certain number of bits is produced. Hence checksum  $S_{c1}$  is generated in response to code  $K_{i22}$  and the content of the request  $U_R$  (step S500).

- 5 A new code  $K_{i+1\_22}$  is generated in response to the old code  $K_{i22}$  and identity information(step S510). This may be done in a manner analogous to step S430.

In step S520 the new code value  $K_{i+1\_22}$  is stored in database 22 as updated code new code  $K_{i22}$ .

- 10 A key comprising the information in the request  $U_R$  and the checksum  $Sc1$  is delivered from the supplier (step S530). This may be achieved as discussed elsewhere in this document, e.g. as discussed in connection with Figure 5A.

- The key, comprising the information  $U_R$  and  $Sc1$  is received in apparatus 14(step  
15 S540). This may be achieved as discussed elsewhere in this document, e.g. as discussed in connection with Figure 5A (S190). A key verification procedure is performed, as discussed in connection with connection with Figure 5A (S200). The key verification procedure includes calculating a checksum. In apparatus 14 the code  $K_{i14}$  is retrieved from memory. The code  $K_{i14}$  and the content of the request  $U_R$  are  
20 used in the above in step S500 mentioned predetermined mathematical algorithm, and a checksum  $Sc2$  with a certain number of bits is produced. Hence checksum  $Sc2$  is generated in response to code  $K_{i14}$  and the content of the request  $U_R$  (step S550).

- In a subsequent step S560, the generated checksum  $Sc2$  is compared to the received  
25 checksum  $Sc1$  (step S560 and step S570). If they are not identical an error message is displayed, as discussed in connection with S210 above in connection with Figure 5B.

- If they are identical then this means that the key is accepted, and the apparatus 14  
proceeds to add the use allowance i apparatus 14 (step S600). Thereafter the user  
30 may use the apparatus, as discussed in Figure 6 (step S610).

When additional usage allowance is desired the user may again request additional use, by following the above described procedure, starting with step S 470 as illustrated in Figure 14A, 14B, & 14C and as described above.



5

Figure 10 is a top view of an embodiment of the apparatus 14, illustrating the physical dimensions thereof. Figure 11 is a side view of the apparatus shown in Figure 10.

- 10 The display 106 has an extension  $x_d$  in a first direction and an extension  $y_d$  in a orthogonal direction such that the display area is at least  $4125 \text{ mm}^2$ .

The apparatus body has a first portion 190 adapted for gripping by a user. The first portion has an extension  $x_1$  in a first direction, an extension  $y_1$  in a second direction.

- 15 The body has an extension  $z_1$  in a third direction, as illustrated in Figure 11. The body also has a second body portion 200 having an extension  $x_2$  in a first direction, and an extension  $y_2$  in a second direction. The second portion comprises at least a part of the display 106.

- 20 According to an embodiment:

$x_1$  is less than 80 mm

$y_1$  is less than 140mm

$z_1$  is less than 35 mm

$x_2$  is less than 100 mm

- 25  $y_2$  is less than 160 mm

$x_d$  is at least 60 mm

$y_d$  is at least 80 mm

- This embodiment provides an apparatus 14 having a body volume of less than  $952\,000 \text{ mm}^3$ , and the display 106 has a display area of at least  $4800 \text{ mm}^2$ . Therefore
- 30 the apparatus 14 is easily portable in a handheld manner, whereas the user interface is advantageously user friendly by means of a large display in relation to the body volume of the apparatus.

According to another embodiment :

- 5        x1 is less than 65 mm  
      y1 is less than 145mm  
      z1 is less than 35 mm  
      x2 is less than 80 mm  
      y2 is less than 145 mm  
10        xd is at least 60 mm  
      yd is at least 80 mm

      This embodiment provides an apparatus 14 having a body volume of less than  
735 875 mm<sup>3</sup>, and the display 106 has a display area of at least 4800 mm<sup>2</sup>. This  
embodiment of the apparatus 14 is even easier to carry in in a handheld manner,  
15 while providing a large display in relation to the body volume of the apparatus.

According to yet another embodiment :

- x1 is less than 60 mm  
      y1 is less than 120mm  
20        z1 is less than 30 mm  
      x2 is less than 80 mm  
      y2 is less than 140 mm  
      xd is at least 60 mm  
      yd is at least 80 mm

25        This embodiment provides an apparatus 14 having a body volume of less than  
552 000 mm<sup>3</sup>, and the display 106 has a display area of at least 4800 mm<sup>2</sup>.

      According to another embodiment the apparatus 14 has a body volume of less than  
1006 250 mm<sup>2</sup>, and said display has a display area of at least 4800 mm<sup>2</sup>. According  
30 to another embodiment the apparatus 14 has a body volume of less than 800 000  
mm<sup>2</sup>.